ICES CM 2009/G:03

CLIMATE-INDUCED SYNCHRONOUS REGIME SHIFTS ALONG ENVIRONMENTAL AND DIVERSITY GRADIENTS IN BALTIC SEA SUB-SYSTEMS

T. Blenckner[1], R. Diekmann[2], C. Möllmann[2], A. Gårdmark[3], M. Casini[4], L. Bergström[3], J. Flinkman[5], B. Müller-Karulis[6], M. Lindegren[7], G. Kornilovs[8], M. Plikss[8]

[1] Baltic Nest Institute, Stockholm Resilience Centre, Stockholm University, Stockholm, Sweden, email: tblen@mbox.su.se, Tel: +46 (0) 86747669

[2] Institute for Hydrobiology and Fisheries Science, University of Hamburg, Hamburg, Germany

[3] Institute of Coastal Research, Swedish Board of Fisheries, Öregrund, Sweden

[4] Institute of Marine Research, Swedish Board of Fisheries, Lysekil, Sweden

[5] Finnish Environment Institute, Helsinki, Finland

[6] Latvian Institute of Aquatic Ecology, Riga, Latvia

[7] Dep. of Marine Fisheries, National Institute of Aquatic Resources, Charlottenlund, Denmark

[8] Latvian Fish Resource Agency, Riga, Latvia

Extended Abstract

Marine ecosystems are currently under strong atmospheric and anthropogenic pressure. Besides natural and human-induced changes in climate, major anthropogenic drivers such as overfishing and eutrophication are significantly affecting ecosystem structure and function. Recently studies demonstrated the existence of ecosystem regime shifts which have been explained mainly as a result of multiple causes, e.g. climatic regime shifts, overexploitation or a combination of both. The occurrence of ecosystem regime shifts has important management implications as they can cause significant losses of ecological and economic resources. Also the Baltic Sea, the largest brackish water body in the world ocean, and its sub-systems are strongly affected by atmospheric and anthropogenic drivers. In recent years climate-induced changes in temperature and salinity, eutrophication and high fishing

pressure had severe impacts on the entire Baltic. To assess changes in the structure and function of the ecosystem and to evaluate the relative effects of the different external forcing factors we performed principal component and regime shift analyses as well as generalized additive modelling using large datasets of hydro-climatic, nutrient, phyto- and zooplankton as well as fisheries variables. We investigated ecosystem structure and function during the period 1979-2006 in 7 Baltic sub-systems, each representing different environmental conditions and food web structures.

The analysis of significant abrupt shifts and monotonic trends of the potential drivers (Baltic Sea Index, water temperature, salinity, nutrients and overfishing) in the different basins indicate that the abiotic variables had a different dynamics in each basin. The winter climate shows an abrupt change in 1989, but no overall trend. The spring surface water temperature, for example, shows no abrupt shift in any basin but two different trends, in Gulf of Riga (positive trend) and the Bothnian Bay (negative trend), without any trend in the other basins. The deep water temperature in summer shows two shifts in the Sound, the Central Baltic Sea and the Bothnian Sea and Bay as well as opposite trends in the Sound (positive) and the Bothnian Bay (negative). Most of the abrupt shifts are found in the winter nutrients (P and N) in combination with increasing trends in the Gulfs and the Bothnian Sea and Bay and decreasing trends in the Sound (P). The fishing pressure shifted in the Gulf of Finland and showed a positive trend in the Central Baltic Sea, Gulf of Finland and Bothnian Bay.

The regime shift tests of all biological variables of the individual basins show first that 1) each basin shows at least one shift over the studied period, 2) most often the shifts occur in the late 1980s and 3) the two different methods applied here (chronological clustering and STARS) show a similar timing of the shifts, except for the Bothnian Sea and Bay.

The overall effect of the drivers on the first and second principal components was tested by applying a generalized mixed additive model (GAMM), using basins as factors and including basin-specific year smothers. The most parsimonious model for the PC1 explains 76 % (n=167, AIC= 716.6) includes only one driver, the BSI ($p<0.01$) and the basin-specific year smoothers ($p<0.001$). All other combinations did not result in any significant model.

Our findings clearly show that sudden transitions are found in all main areas of the Baltic Sea structural changes in multiple trophic levels characteristics. In most basins, the winter

climate and/or temperature could be statistically linked to the change in ecosystem state (principal component 1). Further, this study suggests that different combinations of multiple drivers are required to cause regime shifts in each area of the Baltic Sea.

In conclusion, our study suggests that a combination of stochastic interplay of the drivers can cause an ecosystem-wide regime shift. Further, our study suggests that the combined and synergistic effects of drivers lead to basin-specific regime shifts.

Keywords: regime shifts, food-web, climate, eutrophication